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## Telecommunications For Libraries

The term *telecommunications* encompasses the electronic transmission of voice, data and video information from one, location to another, and includes all physical equipment, software and procedures used in transmitting and receiving that information. Libraries' approaches to telecommunications are undergoing rapid change because of rising telecommunications costs, emerging technologies and the changing needs of libraries.

### Changing Needs

Librarians' needs are changing most significantly in the area of data communications-telecommunication between terminals and computers and among computers. During the 1980s, increasing numbers of remote terminals are being linked to computers as libraries implement patron access catalogs, more consortia install shared automated systems, and use of remote databases continues to grow.

The special data communications needs of libraries are complicated by the fact that most local library systems are minicomputer based, whereas most bibliographic utility, commercial bibliographic service, and remote database vendors' systems are configured around mainframe computers. Minicomputers and mainframes communicate differently; the former normally use asynchronous transmission, the latter synchronous. Most of the literature on data communication emphasizes synchronous transmission.

Synchronous transmission requires a mechanism at each end of the communications channel to synchronize the transmitter and receiver. An asynchronous system uses "dumb" terminals which the computer recog-

nizes by identifying the port of the computer into which the signal is directed. Synchronous transmission uses the telecommunications media more efficiently than asynchronous transmission, but the terminals and communications equipment are usually more expensive.

There is another significant difference between the communications requirements of mini- and mainframe-based systems. Mini-based systems usually involve communications over relatively short distances (fewer than 100 miles)—often, in fact, distances of only a few hundred feet. Users generally require a limited number of linkages rather than a complex, multinode telecommunications network. The remote terminals linked to a mainframe computer are often widely dispersed, with many over 1000 miles distant from the central computer.

When there is a need to access a minicomputer from more than a few hundred feet away, the options are limited by the fact that there is no standard communications protocol for minis. A turnkey vendor may sell a library or consortium an automated library system which permits resource sharing among those who share the computer, but it will probably not offer the capability to interface or electronically link the system with other mini-based systems in the area. It also may not offer the software support which enables the dumb terminals to be used to access remote mainframe-based systems such as Auto-Graphics, Baker & Taylor, Brodart, BRS, Dialog, Dun and Bradstreet, Ebsco, Faxon, OCLC, RLIN, UTLAS, etc. Most of the interfaces which are offered either transfer information from the screen of a terminal of a bibliographic utility system through the printer port and into a local system, or support dial access to a remote database service through a VAV (Value Added Network) which provides special protocol conversion support.

Communications protocols were developed for mainframe computers because the manufacturers had enough users with numerous terminals distant from their mainframes to require sophisticated data communications. IBM's dominant position in the industry led to it setting the de facto industry standard. No industry-wide protocols exist for microcomputers, but most now have software packages which allow them to function as intelligent terminals to mainframe computers.

Because of the mix of requirements experienced by libraries, a great deal of work needs to be done to meet their changing needs in the area of data communications. This would be true even if costs and technologies were stable.

### **Changing Costs**

Costs are changing even more rapidly than needs. In early 1984 the Federal Communications Commission, Congress, and the courts were

grappling with the final details of the AT&T divestiture. Despite the unsettled state of the industry, it was clear that costs would rise. While the news media have emphasized the purchase of telephone equipment, the right to own a telephone is not an effect of divestiture. It came about several years ago as the result of earlier deregulation. It will continue to be possible to lease equipment at rates which are close to the current averages through 1985.

Businesses—including libraries—which leased telephone equipment from a local Bell Company are now customers of AT&T Information Systems (AT&T = IS). Under divestiture, all existing equipment leased from a Bell operating company (BOC) now belongs to AT&T-IS. The agreements made with a BOC will continue to be honored by AT&T-IS. A business customer can choose to purchase the existing equipment, or new equipment, from AT&T-IS or from any one of several competitors. Not all existing equipment will go up for sale at the same time, but by late 1985 all customers will have been given the opportunity to purchase their existing systems. No customers will be required to buy their existing systems; however, after 1 January 1986 there will be no long-term protection against future increases in lease rates or maintenance charges.

Rate changes are a potentially greater concern because they affect libraries' operating budgets rather than their capital budgets. Direct-dial long distance charges are actually expected to drop because long-distance revenues will no longer be used to subsidize local calling. The expected intense competition between AT&T and other long distance companies such as MCI, Sprint, and TDX may also force prices down.

The area of dramatic price increases will be local dial-up service and leased or dedicated line service. This will affect voice and data transmission because both are presently moved mainly over telephone lines. Most video transmission uses alternative transmission media. The average bill for a business user of the telephone system will rise by 50 percent if no steps are taken to change the pattern of use of telecommunications facilities.

Local dial-up services will increasingly be converted to measured service, with rates for limited use of the telephone system comparable to those which now prevail, but with extra charges for calls in excess of a monthly minimum and for time in excess of a monthly minimum. For most libraries, this will affect only voice communication because data and video communication are generally over leased or dedicated lines.

Leased or dedicated voice-grade telephone lines have been the mainstay of data communication. In the past, the rates for such lines have been between \$4 and \$11 per mile per month for limited distances and substantially less for interstate lines. These rates are now expected to rise 60 percent or more. It will, therefore, be more important than ever to maximize the number of terminals sharing a single local telephone line. This can be

done using special hardware that is already available. In most cases the choices will be under the control of individual libraries.

The bibliographic utilities and other remote services present a more difficult problem for libraries because they are accessed through special networks. OCLC, for example, has over 260 leased lines serving 5400 terminals in libraries across the United States. Because the OCLC system is configured around mainframes, the telecommunications network operates synchronously at speeds of 2400 bps and is designed to work exclusively with a custom protocol. Each multidrop circuit services an average of twenty-five terminals. Under the old tariff structure, annual telecommunications billings to OCLC were \$6.5 million; under the new tariff, the figure is expected to increase to more than \$11 million. It will require a major overall system redesign to limit the amount of the increase. While this may be regarded as an appropriate role for the utility, it is of great interest to the libraries because, were OCLC to change the network in such a way as to make existing terminals and modems in libraries unusable on the new network, the libraries would have to replace \$23 million worth of hardware.

### **New Technologies**

The anticipated rise in telecommunications costs has stimulated interest in telecommunications technologies other than the telephone system, but it did not spawn them. Most of the emerging technologies have been under development for more than a decade and are now maturing sufficiently to be seriously considered. Among the alternative technologies are microwave, satellite and cable television. Within a building, the emphasis is on LANs (Local Area Networks), which use coaxial or fiber optic cable to move information.

It should not be assumed that whatever is technologically feasible can be implemented. It typically takes fifteen years from the time that something is technologically feasible until it is in widespread use. There are numerous obstacles to the adoption of a new technology: economics, marketing priorities, and legal and attitudinal constraints. These will be discussed in the context of the specific technologies.

In order to deal with the changes in needs, costs and technologies, librarians will have to develop a basic knowledge of telecommunications. The next section seeks to provide a minimum foundation.

### **Transmitting Information**

Any telecommunications medium distorts the information transmitted over it. A distinct signal suffers degradation as it is transmitted. As the

transmission speed increases, the distortion becomes greater; and as the distance of the transmission increases, the signals also fade.

In addition, "noise" is introduced by external influences on the line. At high transmission speeds, the strength of the noise becomes comparable with that of the signal and errors will occur in the interpretation of the information being transmitted. In all electronic circuitry, there is also a steady continuing background of internal random noise, known as "thermal noise." As the atoms in the communication medium vibrate, they send out electromagnetic waves resulting in a chaotic jumble of electromagnetic waves of all frequencies that provide additional interference to all electronic communication.

If the signal being transmitted fades too much, it becomes irretrievably mixed with the thermal noise. Once this occurs, the two streams can never be separated. And if the signal is amplified, the noise will be amplified with it. If the information is transmitted too quickly or too far, the signal drowns in the noise. To avoid significant distortion in transmissions over long distances, lower speeds must be used. Voice transmission is not significantly affected by these limitations, but data and video information are affected because the amount of information to be transmitted makes it important that high transmission speeds be achieved.

### **Analog *v.* Digital Transmission**

There are basically two different ways in which information of any type can be transmitted over telecommunications media—"analog" and "digital." This distinction applies not only to the type of transmission, but also to the basic characteristics of the medium through which the communication is made. Most telephone lines are designed to carry analog transmissions. In an analog transmission a continuous range of frequencies is generated. A basic signal is always present and information content is transmitted as variations in the nature of that signal. Light, sound, radio waves, and the signals passing along telephone wires are all described in terms of frequency. The signal at a given point oscillates rapidly just as the string of a musical instrument oscillates when plucked. The rate of oscillation is referred to as the frequency and is described in terms of cycles per second.

Normally the sound—or light—reaching the senses does not consist of one single frequency but of many frequencies or a continuous band of frequencies all traveling together. The human voice is a jumble of different frequencies. The same is true of the electrical and radio signals of telecommunications. Usually there is not one single frequency but a collection—or band—of frequencies occupying a given range.



Digital transmission, on the other hand, consists of a pattern of pulses. There is no continuous signal but rather an intermittent pattern of presence or absence of signals. A stream of bits—ON/OFF pulses—is transmitted noncontinuously, in the same manner that data is handled in computer circuits. It is possible to transmit such data at an extremely high bit rate, except over voice-grade (analog) telephone lines or other analog media. Some phone lines have been designed specifically to carry digital data. However, these exist in only a few areas. For most data communication using analog phone lines devices known as modems are used to convert the digital data signals into analog signals for transmission over the analog lines.

Any communications medium—wire pairs, high-capacity coaxial cables, microwave radio links, satellites, and new transmission media, such as fiber optics—can be designed as either an analog or digital medium. If the path is designed to be analog, it will use amplifiers to maintain the signal strength. If the path is digital, it will use repeaters to regenerate the bit patterns and pass them on. A repeater is a power-driven device that detects the bits being sent and then retransmits them with their original strength and sharpness. It catches the bit stream before it is submerged in noise and separates it from the noise by creating it afresh. Consequently, very high transmission rates can be achieved provided that the repeaters are sufficiently close together to catch the bit pattern before it degenerates into noise. On a communications line, the repeaters can be small, inexpensive, solid-state devices.

## **Bandwidth**

The different physical media used for telecommunications vary widely in their transmission capacity. A coaxial cable, for example, can transmit far more information than a simple pair of wires. Analog lines, such as most telephone lines, can handle differing data transmission rates depending on the characteristics of the modems used. A medium's capacity is described in terms of "bandwidth."

Bandwidth refers to the range of frequencies that a channel can transmit. Bandwidth is quoted in "Hertz" or cycles per second; or more commonly in kilohertz (kHz), the number of thousands of cycles per second; or megahertz (mHz), the number of millions of cycles per second.

The bandwidth of a regular analog telephone channel is about 3 kHz and it normally transmits frequencies from about 300 to 3400 hertz, the range needed for transmitting the human voice. Special techniques can be used to raise the frequency base to high frequencies over 8000 kilohertz but this does not change bandwidth which remains at 3 kilohertz. Bandwidth

indicates nothing about the frequency of the transmission; it indicates only the range of frequencies the medium can accommodate.

The capacity of a channel for carrying information is proportional to its bandwidth. A channel with a bandwidth of 30 kilohertz can carry ten times as many bits of computer information per second as a channel of 3 kilohertz. If the speed of transmission is doubled, the time taken to relay the information is halved. Doubling the speed doubles the frequency and also doubles the bandwidth used.

Video transmission requires substantially greater capacity than data transmission and, therefore, is usually accomplished over coaxial cable in a limited area and over microwave and satellite transmission media when long distances are involved.

### **Telephone Lines and Linkages**

The great advantage of the public telephone network for data transmission is its widespread availability. There are telephones virtually everywhere, and wherever there is a telephone, a data transmission device can be connected to the line. However, since the phone system was originally designed to transmit the continuous frequencies of the human voice, it uses an analog signal necessitating the use of modems or other devices to transmit digital data.

There are two common methods of establishing a telephone linkage—dial access and the use of a leased or dedicated line. Almost all voice communication employs dial access, while much communication involves either use of a leased line connecting a single terminal to a single computer or the sharing of a leased line among a number of terminals using multiplexing techniques to link them to a single computer. Video transmission also relies on leased lines when telephone lines are used.

### **Dial Access**

The dial access or dial-up approach is normally used for voice communication. It can also be used for data transmission. The telephone line can be used for voice communication when not in use for data transmission.

All dial-up telephone service is publicly switched. In other words the lines are switched through public exchanges or central offices to make temporary connections.

Dial access is appropriate for situations where a specific terminal-computer linkage is of relatively short and infrequent duration—i.e., entailing only a few dozen transactions a day. The efficiency of dial access,

however, is reduced by the same limitations that apply to regular telephone traffic—peak period loads that make connections difficult to establish and restricted transmission speeds.

Until recently, a major advantage of using dial-up telephone facilities for terminal-computer linkage was economic. Most such installations are within local areas where relatively short distances are involved and local calling rates apply. However, this situation is changing as telephone companies revise their pricing structure and charge business and institutional users by the minute for local telephone calls. Costs are expected to rise further as local rates are restructured to absorb the loss of revenue from long-distance traffic attendant upon the breakup of AT&T. The cost of local dial-up service is expected to increase 60 percent or more between early 1984 and the end of 1985.

Certain technical aspects of dial access of dial access linkage limit the extent to which techniques to increase the speed of data communications—and thus lower the costs—can be applied. Transmission speed, which is usually expressed in “baud”—one baud being one signal element per second—is the major factor. With voice-grade telephone lines and regular modems, the practical upper limit is 1800 baud. Higher speed modems are available. They achieve faster data transmission by encoding more data bits in a baud. For example, a modem operating at 1200 baud, but encoding two bits in a baud, effectively transmits data at 2400 bits per second (bps). Some modems will transmit data over voice-grade lines at 4800 and 9600 bps. A penalty is paid for the very high speed in increased error rates and modem costs. Consequently it is common to limit transmission speeds over voice lines to 4800 bits per second. Unfortunately, the “dumb” terminals used in most local library systems mandate the use of a particular type of modem in dial-up mode effectively limiting the speed of transmission to 1200 bps.

### **Leased Lines**

A leased line may be permanently connected via the local telephone company switching office; but it would not be connected to the switching gear and signaling devices of that office. On the other hand, an interoffice leased connection would use the same physical links as the switched circuits. It would not, however, have to carry the signaling that is needed on a switched line.

### **Other Types of Telecommunications Lines**

Although in many parts of the United States phone companies offer Dataphone Digital Service (DDS) as an alternative to voice-grade analog



lines with pre-1984 tariffs, there were virtually no cost savings to be realized through using DDS even though modems are not required on equipment attached to such lines. However, they offer greater reliability and better performance. There is some evidence that digital phone service will be more attractively priced in the future.

Data communications can be handled through lines other than telephone lines. Telegraph lines, which have a much lower speed of transmission than voice-grade telephone lines, may be permanently connected, or they may be dialed like a telephone line, using a switched public network. Telex is similar; it exists throughout most of the world, permitting transmission at 50 bits per second. Telex users can set up international connections to other countries. Some countries have a switched public network that operates at a somewhat higher speed than Telex, but at lower speed than the telephone lines. In the United States, the TWX network offers speeds up to 150 bits per second. All of these communications lines are designated "subvoice grade" because they are slower than telephone lines.

### **Advantages of Leased Lines**

Given the changes in dial-access pricing structures and the number of transactions per remote terminal per day (300 or more), most libraries can justify leasing a line. The cost now varies from \$4 to \$11 per month per mile, but it can be expected to rise dramatically in the next few years.

There are some real advantages in using leased lines that are permanently connected:

1. If it is to be used for more than a given number of hours per day, the leased line is less expensive than the dial-up or switched line. If it is used for only a half an hour per day, it is more expensive. The "break-even point" depends on the actual charges, which, in turn, depend on the mileage of the circuit; but it is likely to be of the order of an hour to three hours per day.
2. Leased lines can be specially treated or "conditioned" to compensate for the distortion they exhibit. Through conditioning, the number of data errors can be reduced or, alternatively, a higher transmission rate can be achieved. The switched connection, on the other hand, cannot be conditioned beforehand, because it is not known what path the circuit will take. A switched link established when dialing on one occasion is likely to follow a quite different physical path from that obtained by dialing at another time, and there are a large number of possible paths. Modems are now available that condition dynamically and adjust to whatever connection they are used on. These devices enable higher speeds to be

obtained over switched circuits but they are expensive. The common carriers charge extra for conditioning.

3. Conditioned leased lines can often transmit information at a higher rate. Switched voice lines usually carry telephone company signaling within the bandwidth that can be used for data. Consequently, data transmission machines must be designed so that the data does not interfere with the common carrier's signaling. With some machines, this also makes the capacity available for data transmission somewhat less than that over a leased line. A common rate over a switched line in the 1960s was 1200 bits per second, whereas 2400 bits per second was common over a specially conditioned, leased line. Because of improved modem designs, it is probable that in the 1980s speeds of 3600 bits per second over switched lines and 9600 bits per second over conditioned, leased lines will become common. Already some modems transmit at higher speeds than 3600 bits per second over public voice-grade lines.

The cost advantage of switched lines will dominate if the terminal has only low usage.

### **Value Added Networks**

Value Added Networks (VANs) such as Telenet, Tymnet and Uninet lease multiple lines from the telephone companies at substantial discounts and resell the capacity in smaller chunks for data communication. Most users dial up into a local node of a VAN and then pay for the time they use at an hourly rate of \$5 to \$7 per hour. The rate structures are such that only communication over state lines or distances of more than 200 miles are cost effective. VANs provide more than discounted telecommunications lines, however. They add value by introducing network controllers which provide protocols for communicating among various systems. Most libraries using the BRS, Dialog and SDC database services access these systems with an asynchronous terminal through a VAN which converts the protocol to the synchronous one used by the host computers.

### **Simplex, Half-Duplex and Full-Duplex Lines**

The lines in a telecommunications system may transmit in one direction only or in both directions. There are two types of lines which can handle transmissions in both directions: those capable of transmitting in both directions at the same time and those capable of transmitting in only one direction at a time. According to their directional transmission characteristics, lines are classified as simplex, half duplex or full duplex. In North America these terms have the following meanings:

simplex lines transmit in one direction only;  
half duplex lines can transmit in either direction, but in only one direction at a time; and  
full-duplex lines transmit in both directions at once.

Thus, one full-duplex line is equivalent to two simplex lines or two half-duplex lines used in opposite directions. A full-duplex line is often referred to simply as a duplex line. If data is relayed in half-duplex mode, there must be a pause at the end of a transmission to allow a reversal in line direction before a reply can be transmitted and received. The delay during which the direction of the transmission is reversed, is called the line turnaround time. For full-duplex transmission two channels would be used—one transmitting in each direction.

Simplex and half-duplex data transmission require two wires to complete an electrical circuit. Usually a four-wire circuit is needed for full-duplex transmission. There is, however, an ingenious way to build what is, in effect, a four-wire circuit out of two wires—the bandwidth of the lines is split into two separate frequency bands, one of which is used for transmission in one direction and the other for transmissions in the opposite direction. This is referred to as line splitting and produces an “equivalent four-wire” circuit. Although the technique uses only two wires it works as though there were four wires of half the bandwidth. This approach permits full-duplex operation on two-wire circuits. Data transmission machines often have specific requirements as to whether they require a two-wire or four-wire circuit.

Public telephone lines in North America are half-duplex in operation. It is only with leased telephone lines that the user has a choice between half duplex and full duplex. In North America, full-duplex lines generally cost 10 percent more than half-duplex lines.

In North America, simplex lines are not generally used because, even if information is being sent in only one direction, control signals are normally required to be sent back to the transmitting end.

Many data transmission links use half-duplex lines thus allowing the movement of transmittal control signals and the occurrence of two-way “conversational” transmissions. On some systems full-duplex lines provide more efficient use of the lines at little extra line cost. A full-duplex line often costs little more than a half-duplex line. However, data transmission machines that can take advantage of full-duplex lines are more expensive than those that use half-duplex lines. Half-duplex transmission is, therefore, more common at present, although this situation might well change.

## Communications Hardware

In the past libraries have leased hardware for voice communication from the local telephone company and data communications hardware from the same source that provides other computing hardware. However, it is likely that in the future libraries will seek to deal directly with firms specializing in telecommunications equipment. In that case, care must be taken to ensure that all hardware will be compatible and that selections anticipate future as well as current needs. This section describes the major hardware options.

### *Telephones*

Most installed telephones are equipped with a rotary dial, but for several years subscribers have had the option of "touch-tone" or push button equipment which sends electronic pulses suitable for communicating with computer equipment. Rotary equipment is less expensive to lease or purchase. The lease rate for rotary equipment supplied by AT&T is set at \$1.50 per month through the end of 1985, while touch-tone equipment is priced at \$2.85 per month. To purchase existing equipment is \$19.95 and \$41.95 respectively. The touch-tone approach has the advantage of providing access to the various long distance services such as MCI. After dialing the telephone number of a computer, the touch-tone equipment can be used to enter an account number. The typical purchaser can recover the investment in purchased equipment in less than two years. The purchaser assumes financial liability for maintenance when the equipment is owned.

### *Private Branch Exchanges*

When the number of lines at a location exceeds sixteen it becomes practical to consider a Private Branch Exchange (PBX), a switching device for both internal and external calling. Recently, the manufacturers of such equipment have started to offer models which can accommodate both voice and data communication. While this equipment is available from AT&T, the majority of recent installations have featured equipment from a number of smaller vendors. The cost is usually \$1000 to \$2000 per line. The cost per line drops when hundreds of lines are supported.

### *Modems or Data Sets*

As previously described; many of the communication lines over which data are sent are designed for analog transmission—not digital. If computer data is to be sent over such analog lines and there is no PBX with digital capability, it is necessary to convert the digital bit stream into an analog signal using a modem or data set.



A modem converts the bit stream that leaves the computer into a range of frequencies suitable for transmitting over the analog communication line; then, at the other end of the line, a similar modem converts this range of frequencies back into a bit stream that replicates the original data stream. The modem tailors the signal to fit into the range of frequencies that the communication line handles without undue distortion of the signal. Modems range in price from a few hundred to several thousand dollars depending on the data rate for which they are designed.

Most telegraph lines and most wideband lines of higher capacity than telephone lines are analog. Similarly, most of the microwave radio links spanning North America operate in analog, not digital, mode. These links, therefore, must also employ modems when they transmit digital signals. If microwave links or any other communication facility were designed specifically for data transmission—as may happen in the future—they would be digital in operation, with digital repeaters, and thus would not require modems.

### *Multiplexers*

Terminals located in groups at remote sites may be “multiplexed” on a single line using data terminal equipment designed to combine the transmissions of multiple terminals into one composite signal. Several terminals may be connected to a single multiplexer and at the other end of the line over which the signal is transmitted an identical multiplexer reconstitutes the original input from each terminal. In the case of a minicomputer, the equipment routes the signals to the appropriate ports of the computer or to yet another multiplexer. Neither terminal equipment nor the computer hardware or software need be changed when multiplexing is undertaken. Either dial-up or leased lines may be used with multiplexers. Most multiplexers have built-in modems.

There are several multiplexing techniques, the most cost effective of which is usually statistical multiplexing. A statistical multiplexer uses a small microprocessor and a buffer memory so that data can be stored temporarily during periods of peak activity. This permits more terminals to share a line because the “stat mux,” as it is often called, smooths out the traffic flow. It allocates the shared line in such a way that up to eight terminals, each operating at 1200 bps, can share a single 1200 baud voice-grade telephone line transmitting at 2400 bps. Another term now more commonly used by manufacturers of this high capacity equipment is *data concentrator*.

Stat muxes typically cost from \$2,500 to \$10,000 each depending upon the number of terminals they handle and whether they include a built-in modem. A rule of thumb is to budget \$2000 per terminal. The special

modems required for use with data concentrators may cost as much as \$6000 a pair.

It is possible to network stat muxes or data concentrators. For example several terminals at a branch library may share a multiplexer that is connected to another multiplexer through a pair of modems. In turn the second multiplexer connects with yet another multiplexer. Several other terminals may also come into the third multiplexer directly and all may share a single line to the central processor. The multiplexer at the central site splits all the transmissions among the appropriate ports of the computer.

The advantage to concentrating terminals is realized when the costs of the individual telephone lines (if any) from the terminals to the multiplexers, the telecommunications hardware and the shared multiple line charges are added up and found to be less than the cost of the larger number of individual telephone lines and modems.

#### *Multidrop Concentrators*

Related to the data concentrator is the "multidrop concentrator." This device allows a single telephone line to connect individual terminals or clusters of terminals which are multidropped—i.e., configured with nodes at several points along the telephone line rather than just at each end. The multidrop concentrator at the central site—a processor—would poll or communicate with all of the node concentrators in round-robin fashion. Unlike the polling techniques used in synchronous communication, intelligent terminals are not required. The cost of a multidrop concentrator is \$3500 or more and the node concentrators cost up to \$2500 each.

#### *Port Concentrators*

Another related piece of telecommunications hardware is the port concentrator or intelligent port selector. It allows one computer port to communicate with several terminals, not just in dial-up situations, but also when leased lines are used. As a transmission comes in, it is directed to any vacant port rather than to a port preassigned to that particular terminal. Unlike the other multiplexing devices discussed, a port concentrator does require some changes in the computer system software.

### **Non-Telephone Options**

The thinking on the design of data communications systems is changing. No longer are telecommunications networks seen as being composed of one communications medium. Development is moving toward a multimedia approach which combines telephone with one or more other

media such as satellites—cost effective for distances in excess of 700 miles, microwave and cable television—for local transmission, and Local Area Networks (LANs) for short distances. Implementation of multimedia data linkages is likely to be hampered by high start-up costs and by FCC regulations which require that data communications applications using media other than the telephone lines be licensed.

### *Satellites*

Satellite channels offer very high speed and capacity because the frequency is in the billion cycles-per-second range. Satellite channels also provide low error rates because they are not subject to atmospheric interferences.

In order to utilize a satellite for voice, data or video communication, the user must have a connection to the central office of the satellite communications vendor. The local telecommunication loop as it is called usually utilizes local telephone lines to transmit the voice or data to the terrestrial (earth-based) station. Video is usually sent to the terrestrial station over a specialized cable linkage or by microwave.

The major costs in establishing a satellite circuit are those of the terrestrial stations which exchange signals with the satellite, the central office facilities and the satellite itself.

The cost of an earth station capable of both transmitting and receiving is approximately \$70,000. The satellites cost millions of dollars each to build and place into orbit. Because capacity is limited there is great competition for access to the facilities. Lease costs for a satellite transponder—capable of supporting the equivalent of 1000 telephone lines—begin at about \$13 million per year. A single 56-Kbit (56,000 bits per second) circuit costs at least \$10,000 per month.

Since the satellite is in orbit 22,300 miles above the earth, it will always appear stationary vis-à-vis the ground station and the signal always travels approximately the same distance. The cost of using the channel is, therefore, the same whether the sites being connected are Washington and Los Angeles or Washington and Baltimore. It is generally not cost effective to use satellite communication for distances shorter than 700 miles because telephone lines or microwaves involve lower fixed costs and thus lower rates.

### *Microwave*

Microwave communication is the most common form of terrestrial or earth-based long distance transmission for voice, data and video. A single microwave transmission can carry 600 to 1800 voice channels. Using space as the transmission medium, microwaves are beamed from an origination

point at which many individual messages have been collected by telephone lines, cable or other means. Because transmission of the microwave beam requires a straight, uninterrupted line-of-sight path, the transmitting towers are sited on hills or tall buildings to minimize interference. Usually towers are placed no more than thirty miles apart. Greater distances are not practical because the curvature of the earth causes the message stream to go into space rather than remain earthbound.

When transmission volume is high and distances exceed twenty-five miles, microwave usually is less expensive than telecommunication options which require the laying of special cables. This is particularly true when right-of-way must be obtained for cables. However, atmospheric interference is a factor; rain can cause severe transmission problems with microwave communications. Moreover, in metropolitan areas where many short microwave links exist, the available spectrum is becoming crowded and further installations are not possible.

The cost of constructing a single line-of-sight microwave tower is approximately \$50,000. Maintenance costs are approximately \$250 per channel per year. It is normally not practical to construct a microwave network for a group of libraries because the transaction levels are not high enough to offset the high start-up costs. It is sometimes possible to utilize excess capacity in existing fire, police or educational microwave systems. The major risk of this arrangement is that the excess capacity may eventually be claimed by the original users and service to the libraries discontinued. It must also be kept in mind that telephone lines or other linkages between the libraries and the microwave facilities will represent a major ongoing cost.

### *Cable TV*

There has been considerable interest in the use of cable television systems for data and video transmission. As with telephone lines the cables can be used to transmit data exclusively or intermingled with other information.

Cable as a communications medium offers high capacity, speed and relatively widespread availability. However, to install a cable system specifically and solely to link a number of sites which wish to exchange voice, data or video communications is prohibitively expensive except in very localized, high volume situations. It involves getting the cable to all of the locations and the installation of equipment to link the telephone, computer system and/or video facilities to the cable network.

Voice communication is rarely transmitted over cable television facilities. There is currently only one cable television company which has provided a cable-based data communications system—Manhattan Cable.



The company provides cable-based data communications to 200 high-volume banking and financial customers through an installation of only seventeen miles of cable. Each account contributes at least \$200,000 a year to Manhattan Cable's revenue. Applications for licenses to use cable in this way have been filed in only four other communities.

The use of cable for video is widespread. Libraries have been relatively successful in having cable facilities and access provided as part of the franchise agreement between a community and a cable company.

There is not yet enough experience to permit judgment of whether or not cable is a viable alternative for voice and data communication, but claims have been made by enthusiasts that if voice and data communication were to piggy-back on a cable television system, the costs could be reduced 10 to 40 percent below that of current telephone communications.

There are, however, constraints, especially with regard to the use of cable television systems for data communication. The medium must be capable of two-way/interactive communication. At the simplest level, a terminal operator needs to transmit a search request and be able to receive the results of the search—i.e., to transmit a message requesting that an item be placed on hold and to receive confirmation that the message has arrived. In practical, economic terms such capabilities are only available on cable television systems which have been designed as two-way systems. Only 1 percent of the U.S. communities which have cable television have such two-way services. Even in installations with this capability, library use of a cable channel for data communications requires that the system have spare channels not currently devoted to other applications. The majority of installed systems do not have spare capacity although most recently awarded franchises do have a number of unused channels.

Should a library be in a situation in which both of these requirements are met, the way is still not clear for the use of cable as a data communications medium because most cable companies are not yet interested in supporting data communication. Factors such as company priorities and economics will be keystones in determining the future of the medium. Until cable companies are convinced that data communication will be profitable and within their technical capabilities, little will happen. At present, no library in the United States is using cable as an operational system for data delivery.

While cable has the potential to offer better and cheaper channels for data transfer, quality control can also be a problem—some systems do not offer satisfactory performance.

### *Local Area Networks*

There has been a great deal of promotion of Local Area Networks—i.e., the wiring of a building or contiguous buildings to permit

voice, data and video systems to be plugged in and interconnected. The most widely advertised systems are Ethernet, Xerox's X10, and Wangnet. While Ethernet is now supported by 34 companies, the claimed compatibility is nothing more than an undertaking by the equipment manufacturers to stay out of one another's way; equipment from different vendors can share the channel but cannot exchange information. Xerox's LAN is supported by only a few companies and Wangnet can only accommodate that company's hardware.

The cost of an interface between any piece of equipment and Ethernet is now \$950, but this may drop to \$300 or \$400. If a new building is prewired, there can be cost savings for connecting compatible pieces of equipment without having to lay new cables.

Transmission media for local area networks include twisted-pair wire, baseband and broadband coaxial cable, and fiber optics cable. The most popular are the two types of coaxial cable. In baseband systems the information is encoded as a digital signal that is transmitted directly; only one signal can be present at any instant, and the signal uses the entire bandwidth. When used for data communication, a baseband system can have a data rate of 50 megabits per second; broadband can support 200 megabits per second. A broadband system permits several information signals to be present simultaneously.

Baseband systems—the type most widely marketed as LANs—are normally limited to 1.5 miles and can support hundreds of nodes. The cable costs are 10 to 15 cents per foot plus installation. Broadband techniques can support distances of up to 200 miles at cable costs of 15 to 25 cents per foot plus installation. A number of college campuses are planning the installation of broadband systems for voice, data and video communication.

### *Fiber Optics*

Fiber optic cables are beginning to appear in short distance, high-capacity communications situations. Fiber optics is the technology of producing glass or plastic cables through which light can pass for long distances with only a slight loss of intensity. A laser is used as the light-producing medium. It is possible to transmit much more information in the form of light than as electrons through conventional copper or coaxial cables of comparable diameter.

In the next ten years fiber optic cable is expected to displace both conventional telephone lines and coaxial cables in high volume communications environments. Microwave, now usually used for high traffic communications over distances of 25 to 700 miles, is also expected to be affected by the growth of fiber optic systems.

### **Video Communication, a Special Case**

The distribution of video has been very limited outside the commercial television industry due to lack of adequate transmission facilities. While available telephonic communications systems will support voice and data communication in a reasonable and cost-effective manner, they do not provide adequate facilities for video communications.

The appropriate medium for video communications requirements will continue to be provided by a cable system separate from the telephone system. The system may be a cable television system or a LAN, and it may be dedicated to video communications or shared with voice and data communications.

As was mentioned earlier, there are two types of cable systems available—baseband and broadband. The baseband offers a fraction of the capacity of a broadband and can be carried as a “channel” on a broadband system. Baseband systems can be compatible with broadband systems and may be useful in intrabuilding networks. However, broadband cable systems are superior for multibuilding networks when video distribution is contemplated. As a general rule, a broadband single 1.5-inch coaxial cable with a 300 mHz signal will support thirty video circuits. A video channel requires a 6 mHz bandwidth.

### **Evaluation of Near-Term Options**

Because of the changing needs of libraries and changes in the costs of telecommunications, librarians managing automated systems will need to periodically reexamine their telecommunications approaches. If a library's telecommunications costs are more than \$1000/month or have risen more than 20 percent in the past year, a review should be undertaken. In the near-term this will consist of reevaluating the use of telephone systems; in the longer term it will involve the examination of other technologies. The following rules of thumb are valid at the present time:

1. If terminals are within 2000 feet of the computer, direct connections using line drivers are generally most cost effective.
2. When terminals are remote from the computer, but widely scattered, direct connection through telephone lines with modems may be cost effective. Normally, dedicated leased lines are more cost effective than dial-up lines.
3. If the remote terminals are concentrated at a small number of sites; if there are more than twenty-five remote terminals; or if telecommunications costs are more than \$1500 per month, it is quite likely that the use of statistical multiplexing will be more cost effective than modems.

4. If there are more than fifty remote terminals, it may be possible to network statistical multiplexers to realize even greater cost savings.

Some libraries may be able to reduce ongoing telecommunications costs by up to 90 percent by investing in the telecommunications hardware discussed in this paper. The "payback" period—the time required to recover the capital outlay for telecommunications hardware—may be as short as two to three years.

While a library may wish to have the vendor of its computer system review and modify its telecommunications it is not mandatory that it do so. Virtually all telecommunications hardware requires no changes in software. A library may choose to retain an expert in telecommunications if its vendor does not appear to have appropriate expertise or if the vendor's prices for a telecommunications analysis are too high.

The vendor should be notified of planned changes in the telecommunications system as should the telephone company(ies). Despite frequent protests by vendors and telephone companies, they may not prohibit the use of telecommunications equipment purchased from other sources.

### **Interfacing Computer Systems**

The interfacing or electronic linking of various computer systems will increase libraries' need for telecommunications, but telecommunications will not be a major obstacle to such interconnections. The dominant issues will be technological, economic and political. Hardware, software and database design will have to be made compatible or interconnection standards will have to be adopted. The cost of interfacing will have to be worth the perceived benefits. Most of all, the various competing vendors will have to be persuaded that interfaces to other systems—even those of competitors—are a requirement of the library community. When these issues have been successfully addressed there will be a wide range of choices for actually transmitting the information.